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IS MUNICIPAL SEWAGE SLUDGE A RESOURCE FOR AGRICULTURE?

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Spreading of treated municipal sewage sludge on agricultural land has become an increasingly attractive method of sludge disposal for many Ohio cities. Several events have accounted for this growing interest. First, the Federal Water Pollution Control Act Amendments of 1972 encouraged municipalities to construct sewage treatment facilities which provided for the "recycling of potential sewage pollutants through the production of agriculture..." Second, the Act and subsequent federal regulations provided for grant assistance to local municipalities in the construction of sewage treatment facilities. Finally, the municipalities were required to consider alternative waste management techniques including landspreading of treated sludge in applying for grant assistance.

While these legal mandates encouraged landspreading, recent price changes also have had an impact on the acceptability of landspreading. Energy shortages including natural gas shortages have resulted in higher nitrogen fertilizer prices. Farmers have been more willing to accept commercial fertilizer substitutes and have begun to view sewage sludge as being such a substitute. In addition, farm prices have risen dramatically over the past three years due to a combination of events - increased worldwide demand due to rising standards of living, increased demand for grain from Communist bloc nations, devaluation of the dollar, and short supplies in many countries. These output price rises have increased the demand for fertilizer and fertilizer substitutes such as sewage sludge.

While the popularity of applying sewage sludge to land has increased strikingly over the past few years in recognition of the potential for recycling pollutants and increasing agricultural production, many have warned of potential damages from sewage sludge. Concern has been expressed that surface water quality may deteriorate due to runoff from landspreading fields, ground water may receive excessive levels of chemicals from leaching, soils may be permanently damaged due to the presence of toxic materials which inhibit plant growth, plants may take up and accumulate heavy metals which may be dangerous to plant growth and human health, viruses or other pathogens may create potential health problems for those contacting sludge, nuisance odors may result, and so forth. For a critical evaluation of these problems, the reader is referred to recent reviews such as Sopper and Kardos (1973), EPA, USDA, and NASULGC (1973), and Miller and Pettyjohn (1974). Indeed, the list of reasons why land application of sludge should be discouraged is as long as the one which professes its benefits.

These views of the advantages and disadvantages may both be accurate. Sludge may be a valuable product, <u>but</u> the chemical analyses of the sludge must be closely monitored. Similarly, the application rates and techniques must be closely supervised to assure that potentially dangerous chemical components are applied at safe levels. The soils to which sludges are applied should be monitored to prevent a build up of toxic substances and long term damage to the soil. Application technique and site selection should prohibit runoff of sludge into nearby streams. The soil structure and subsurface geology should be evaluated in order to assure that leaching of chemicals into the groundwater does not occur. In short, careful design and management may assure that sludge is a valuable resource rather than a pollutant injurious to soil, water and health.

Use of Municipal Sewage Sludge on Land in Ohio

Results of a recent survey of Ohio municipalities illustrate the wide range in sludge application practices. The survey, sponsored by the Ohio Farm Bureau Federation, the U.S. Environmental Protection Agency, and the Ohio Agricultural Research and Development Center, was aimed at identifying the extent of sludge landspreading and the current methods and practices in landspreading. Personnel from the Ohio Farm Bureau (OFB) and the Ohio Municipal League (OML) assisted in the interview process. A study by Carroll, et al. (1973), identified 35 communities in Ohio which spread sludge on land, and these communities were visited by OFB personnel. In addition, a questionnaire was sent by OML to a sample of Ohio cities not included in the list of 35 communities, and an additional eight cities were identified as practicing landspreading.

The following list contains the names of 43 cities which were surveyed and were spreading some or all of their treated sludge on land. This list is not a complete inventory of Ohio cities which landspread. It is statistically probable that an additional 10-15 landspreading communities were not identified by the research team making a total of 50-60 cities which currently are spreading sludge on land.

Archbold
Ashtabula
Bowling Green
Bryan
Celina
Conneaut
Coshocton
Dayton
Defiance
Findlay
Greenville
Grove City
Heath
Hillsboro
Lakewood
Lancaster
Lebanon
Lima
Madison
Mansfield
Marietta
Montgomery Co.
Newark
New Philadelphia
Norwalk
North Olmstead
Painesville
Perrysburg
Piqua
Sandusky
Sidney
Springfield
Toledo
Toronto
Troy
Upper Sandusky
Vermillion
Wapakoneta
Washington C.H.
Willard
Wilmington
Xenia
Zanesville

The combined sewage flow from these cities which required treatment was about 320 million gallons per day. From this flow approximately 100 dry tons of sewage sludge was generated each day. The problems faced by communities is how to dispose of this sludge in an economical and environmentally safe manner.

The quantity of land used by these communities in landspreading was only a small portion of the available acres. If all the sludge from the estimated 50-60 Ohio cities using landspreading was applied to the land at environmentally safe rates (usually less than 10 tons per acre), less than 1% of the harvested crop acres in Ohio would be covered each year. Thus, sludge application to land does not provide a substantial proportion of crop nutrients.

The small acreage receiving sewage sludge each year does not mean that landspreading of municipal sludge is unimportant to farmers and rural residents. First, due to the limited number of disposal alternatives and the recent emphasis on environmental quality, landspreading likely will increase. Second, the persons affected by landspreading may extend far beyond the farmers on whose fields the sludge is actually spread. The local rural community may bear costs such as odor nuisance and deteriorating quality of the ground and surface waters. Future generations also may bear the burden of land which has suffered detrimental effects as a result of excess loading rates. Furthermore, these effects may have an impact on local land values and the economic growth of the community. Caution must be used by landowners, the disposing municipality, and the local community at large in order to assure that the long run benefits are larger than the costs for the entire community. Landspreading must not be looked upon as only a disposal technique, but as a tool which municipalities possess that may be beneficial or detrimental to the entire community.

Current State of the Arts in Landspreading

The application rate suitable for a particular disposal site is dependent upon two primary factors - the chemical characteristics of the sludge and the properties of the soil receiving the sludge. The chemical contents of the sludge is a limiting factor in determining safe application rates. Heavy metals must be monitored to assure that plant growth is not adversely affected. The chemical and physical properties of the soil partly determine the availability of toxic heavy metals for plant uptake, movement of phosphates into groundwater, leaching of nitrates into groundwater, and soil erodibility and drainage.[1]

Testing and Monitoring

The survey of Ohio cities using landspreading provided a picture of the extent of testing and monitoring programs. The majority had at least a minimal analysis program of the sludge being applied to the land. Only nine cities, out of the total 43 surveyed, did not have some type of sludge analysis program (Table 1). Furthermore, 23 of the cities analyzed their sludge monthly or more often with several analyzing the sludge daily (Table 1).

Generally, the analyses were one of two types. Either the city analyzed only the solids and volatile solids contents of the sludge, or they performed costly analyses of the solids, volatile solids, primary nutrients, and heavy metals. Of the 43 surveyed cities which spread sludge on land, 16 cities performed the minimal analysis while 18 ran the more

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[1]Soil limitations are discussed in the Ohio Guide for Land Application of Sewage Sludge, Bulletin 598, Cooperative Extension Service, Ohio State University.

detailed analyses (Table 2). Those cities using no sludge analysis program or a minimal program are applying sludge without adequate knowledge of the characteristics of the sludge and the suitability of the sludge for soils in their area.

Several of the smaller communities had limited knowledge of the contents of the sludge which they applied. Of the 11 cities with less than 2.0 million gallons per day sewage flow (MGD), 4 cities did not have a sludge testing program (Table 1), and 3 cities tested their sludge less than once every six months.[2] The majority of smaller communities (less than 2 MGD) appeared to have rather limited analyses to assist them in applying sludge at safe rates with only 2 of the 11 cities having a thorough analysis program (Table 2). Generally, the larger communities have had the resources to establish a regular and more thorough sludge testing program. Of the 32 communities with capacity of 2 MGD or greater, only 5 communities did not test the sludge, and 16 of the 32 cities had a thorough testing program with some knowledge of the nutrient and heavy metal content of the sludge (Table 2).

The relative lack of knowledge of sludge contents on the part of small cities does not imply that they are putting sludge on at unsafe rates. Of the cities responding to the question concerning the rate of application, most appeared to be applying sludge to private land at low to moderate rates (less than 10 dry tons per acre per year).

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[2]MGD is an abbreviation for million gallons per day.

Table 1. Sludge Testing Program by Size of City Involved in Land Application

Capacity (MGD)[a]	Number of Cities in Category	Number of Cities Testing Sludge				
		Weekly	Monthly	Quarterly	Semi-Annually or Less Often	Not Testing
< 2.0	11	4	0	0	3	4
2.0 - 3.9	9	4	1	0	2	2
4.0 - 7.9	10	5	1	0	2	2
8.0 - 19.9	9	3	2	1	2	1
> 20.0	4	2	1	0	1	0
Total	43	18	5	1	10	9

[a]MGD = million gallons per day

Table 2. Type of Sludge Analysis Program by Size of City Involved in Land Application

Capacity (MGD)[a]	Number of Cities in Category	No. Cities Using Analyses Program[d] No Analyses	Minimal[b] Analyses	Thorough[c] Analyses
< 2.0	11	4	5	2
2.0 - 3.9	9	2	2	5
4.0 - 7.9	10	2	4	4
8.0 -19.9	9	1	4	4
> 20.0	4	0	1	3
Total	43	9	16	18

[a]MGD = Million Gallons Per Day

[b]"Minimal" includes analyses for total solids content and volatile solids in the sludge.

[c]"Thorough" includes analyses for solids content, volatile solids, some primary nutrients (Nitrogen, phosphorus, potassium), and some heavy metals (cadmium, zinc, copper, nickel, boron, chromium, cobalt, manganese, mercury, molybdenum, lead).

[d]Cities have a choice of building their own laboratories to analyze their sludge or to use the services of a commercial laboratory. The cities which perform only minimal analysis tended to analyze the sludge in their own laboratories. Approximately two-thirds of these cities used their own laboratories. On the other hand, the cities performing detailed analysis tended to use commercial laboratories for some or all of their testing. Twelve of the 18 cities with a "thorough" program used commercial laboratories.

Several Ohio communities were testing soils before application and were monitoring soils to which sludge was applied. However, the majority of cities appeared to have little knowledge of the capacity of the soils to effectively utilize the sludge. Only 4 of the 43 cities surveyed were testing the soil prior to application and only 8 were monitoring the soil after application (Table 3).

It is also suggested that "water sources originating near the sludge application area...should be periodically sampled and tested for the presence of trace elements and nitrates." (Ohio Guide, page 11.) Water quality near disposal sites was being monitored by nearly one-third of the communities (Table 3). Furthermore, there was little variation in the proportion of cities monitoring water quality between size categories of cities above 2 MGD.

It is suggested that plant tissue and the harvestable portion of the plant be monitored for heavy metal uptake. Plant tissue was being monitored by about the same cities that were monitoring soil type. This small group of cities were following recommended monitoring practices, they had adequate knowledge of the sludge they were applying, and were monitoring the plants and soils to assure proper sludge application and renovation.

Application Equipment

Equipment used in sludge disposal largely consisted of tank trucks with gravity discharge or tank trucks with pumped discharge (tank trucks include tank wagons pulled by tractors). The irrigation-sprinkler system was not being used by Ohio cities. Furthermore, the irrigation-overland flow system was found in only 4 of the cities interviewed (Table 4).

Table 3. Soil Testing at Disposal Site and Monitoring of Disposal Site by Size of City

Capacity (MGD)[a]	Number of Cities in Category[b]	Number of Cities			
		Testing Soil Prior to Application	Monitoring Soil After Sludge Application	Monitoring Water Quality Near Disposal Site After Sludge Application	Monitoring Plant Tissue On Disposal Site After Sludge Application
<2	11	0	0	1	1
2 - 3.9	9	1	2	4	2
4 - 7.9	10	2	2	4	2
8 - 19.9	9	0	3	3	2
>20	4	1	1	2	1
Total	43	4	8	14	8

[a] MGD = million gallons per day

[b] Several cities do more than one of the activities of soil testing, soil monitoring or plant tissue monitoring; therefore, the sum of the number of cities doing alternative testing and monitoring programs does not equal the number of cities in each category.

Table 4. Method of Treated Sludge Application by Size of City

		Number of Cities Spreading Sludge by				
Capacity (MGD)[a]	Number of Cities in Category[b]	Irrigation Overland Flow	Tank Truck With Gravity Discharge	Tank Truck With Pumped Discharge	Tank Truck With Soil Injection	Spreader
<2	11	1	6	4	0	2
2.0 - 3.9	9	2	2	4	1	2
4.0 - 7.9	10	0	4	6	0	0
8.0 - 19.9	9	0	4	4	1	3
>20	4	1	1	0	0	2
Total	43	4	17	18	2	9

[a] MGD is a measure of flow through the plant. It is an abbreviation for million gallons per day.

[b] The number of cities in each size category are from the Municipal Sewage Sludge Survey. Some cities use more than one type of disposal; therefore, the sum of the number of cities using alternative methods of disposal does not equal the number of cities in each size category.

Landspreading of sludge by box spreader was found in several communities where the treatment process resulted in a sludge with relatively high solids content.

The majority of cities spreading sludge by tank truck were using tanks with less than 2,000 gallon capacity. A few cities had larger trucks with the potential to cause soil compaction problems if used directly for field applications. Some of the larger capacity trucks were being used solely for transportation with sludge transferred to smaller application trucks at the disposal site.

Social Aspects

Favorable community reaction is a requirement for a successful landspreading program. A few Ohio municipalities learned this fact when local objections were voiced against their landspreading efforts. However, the vast majority of communities have held a favorable attitude according to sludge disposal personnel. Approximately 80 percent of the treatment plant operators applying sludge to land ranked their community's reaction as either favorable or enthusiastic (Table 5).

One key to community acceptability of a landspreading program is early involvement of the landowners and general public near a potential landspreading site. Owners of potential landspreading sites and those who might be affected by the site should be provided information concerning landspreading of municipal wastes. The municipality should plan to educate the citizenry about its intent to manage the site in a manner which is beneficial to the total community.

Contracts between landowners and the communities producing the sludge are viewed by many as a solid foundation for a favorable relationship

Table 5. Treatment Plant Operators' Estimation of Their Community's Reaction to Sludge Disposal by Size of City

Capacity (MGD)[a]	Number of Cities in Category	Number of Cities Where the Community Reaction Has Been				
		Enthusiastic	Favorable	Unfavorable	Very Negative	Don't Know
<2	11	0	10	0	1	0
2.0 - 3.9	9	1	6	0	1	1
4.0 - 7.9	10	0	7	2	0	1
8.0 - 19.9	9	4	4	0	0	1
>20	4	0	3	0	0	1
Total	43	5	30	2	2	4

between the producer and the recipient. Approximately 20 percent of the communities surveyed had written leases and provisions in these leases included one or more of the following points -

1. escape clause for both parties
2. prohibition of any damage occurring to the physical or chemical characteristics of the soil
3. restriction to the type of crops grown on the disposal site
4. restrictions on application during growing season and on application when soils are wet
5. restrictions on application rate
6. placement of any liabilities due to odor, runoff, etc. with farmer

The last provision would seem unfair to the farmer recipient unless the analysis of the sludge is known by the farmer. Making the farmer solely liable for the effects of the sludge would be equitable only when the city is able to provide a detailed analysis of the sludge and is assured that the farmer has been informed of the potential hazards of application.

The principal advantage of a written contract is to make sure that both parties understand the agreement prior to applying the sludge. Often oral contracts are entered with the best of intentions, but the landowner and municipality have differing notions of the rights and obligations of each party.

Suggested provisions of contracts between municipality and landowner include -

1. Identification of the landowner and governmental unit spreading the sludge.

2. Location of land where spreading is to occur and boundaries of application.

3. Entrance and exit points to land which disposal trucks will be using.

4. Specification of range of sludge quality permitted on land. Parameters identified might include percent of total solids, cadmium/zinc ratio, levels of zinc, copper, nickel, chromium, and cadmium.

5. A periodic analysis of the sludge which would provide the farmer with levels of nutrients (nitrogen, phosphate, potash, and trace elements) available in the sludge. Monitoring of the soil and plant tissue may also be desirable. The contract would specify who is to pay for the analysis and monitoring and their frequency.

6. Agreement on disposal during the cropping season. Application rates and acceptable periods of application should be identified for growing crops.

7. Agreements on disposal during periods when the soil is wet.

8. Agreements on the application rate. This rate might vary throughout the year depending upon the contents of the sludge and when and where application is occurring.

9. Restrictions upon usage of land for root crops, fresh vegetables or livestock production.

10. Agreement as to the system of farming. If the city needs a certain number of acres during the cropping season, then the cropping pattern should be identified as well as the tillage, planting and harvesting schedule.

11. Conditions under which either party may escape from provisions of the contract.

12. Arbitration procedure in case of disagreement between the parties.

Economic Considerations

There is continuing pressure on communities to find less expensive and more environmentally favorable sludge disposal methods. Furthermore, farmers often view sludge as a resource which may be a substitute for a portion of their increasingly expensive fertilizer requirements. This section summarizes the costs of landspreading and the benefits accruing in the form of a nutrient supply.

The surveyed cities were asked to identify their (1) capital investment in sludge disposal equipment and storage facilities, (2) the average

age of these capital investments, and (3) the annual operating costs of sludge disposal. The capital investments were compounded by an annual rate of 5 percent over the life time of the investments in order to have all investments in current dollars. The total annual cost for each disposal system was the sum of depreciation, interest, repair and maintenance, labor, insurance, fuel, administrative, and miscellaneous expenses.

The data from the survey indicated that average sludge disposal cost per unit of treated sewage declined as flow increased until the plant was treating approximately 25 MGD. At this level disposal costs were $24.85 per dry ton. At 25 MGD flow, average costs increased slightly as plant size was expanded (Table 6).

The mean plant size in the surveyed communities was 8 MGD. The average cost of sludge disposal at this size was approximately $31 per dry ton. For plants smaller than the mean size, disposal costs increased rapidly. The plant with 4 MGD flow had an average sludge disposal cost of $43 per dry ton.

Sludge disposal costs shown in Table 6 are estimates of total costs and average costs for cities of alternative sizes. These estimates were calculated with the cost data furnished by the surveyed cities. While variations in costs were seen at each plant size, the model used to calculate the costs shown in Table 6 explained 87 percent of the variation in costs between cities. The model is explained briefly in the footnote under Table 6.

Table 6. Estimated Average Total Cost for Surveyed Cities

Size (MGD flow per day)[a]	Annual Total Cost[b] ($)	Annual Average Total Cost Per MGD Flow $/MGD	Average Total Cost Per Dry Ton[c] $/dry ton
2	15562	7781	69.70
4	19657	4914	43.40
6	23881	3980	35.10
8	28235	3529	31.10
10	32720	3272	28.90
12	37334	3111	27.50
14	42078	3005	26.50
20	57091	2854	25.20
30	84712	2823	24.90
40	115583	2889	25.50

[a]MGD flow = million gallons per day flowing through treatment plant.

[b]Depreciation is assumed to be 12.5 percent of investment (current dollars), and interest is assumed to be 8 percent of midlife value of investment (current dollars). Total cost is sum of depreciation, interest, repair and maintenance, fuel, labor, insurance, administration, and miscellaneous expenses. Ordinary least squares was used to arrive at the following function:

$$\text{total cost} = 11598 + 1949.67\,(\text{size}) + 16.25\,(\text{size})^2 + 16821\,(\text{dummy})$$

The variable "size" equals the flow per day through the plant in million gallons. The variable "dummy" is equal to 1 when the municipality owns disposal land and 0 when no land is owned. All coefficients are statistically significant at the .10 level.

[c]The following function was established from the survey -

$$\text{Dry tons} = .32 + .311\,(\text{size})$$

where "size" equals the flow per day through the plant in million gallons. The coefficients are statistically significant at the .01 level. Annual costs per MGD were converted to costs per dry ton by the following formula -

$$\text{cost per dry ton} = \left(\frac{\text{annual cost per MGD}}{365}\right) / .31$$

The benefits of sludge may be approximated by the value of sludge as a substitute for commercial fertilizer. These substitutes are the nitrogen, phosphate and potash required by crops. However, the variable chemical composition of sludge and fluctuating nutrient prices make the benefits difficult to calculate.

On the average, a dry ton of sludge contains approximately 100 pounds of nitrogen, 100 pounds of phosphate and 5 pounds of potash. Only about 30 percent of the total nitrogen from sludge is immediately available to the plant. This combination of nitrogen, phosphorus and potassium is not suitable for most crops. For example, typical fertilizer rates for corn are 180, 50, and 60 pounds per acre of nitrogen, phosphorus and potassium, respectively. If 6 dry tons of sludge per acre are applied, the sludge would furnish 180 pounds of nitrogen, 600 pounds of phosphate and 30 pounds of potash. Thus, phosphorus buildup likely would occur and potassium fertilizer supplements might be required on low potassium soils. Sludge application cannot be expected to replace commercial fertilizers but only to supplement them. Rather, applications of commercial fertilizers would be required on most soils to achieve an acceptable balance of nutrients.

The value of sludge as a fertilizer may be reduced drastically by excessive concentrations of trace elements. Sludges high in trace elements may present problems to crops and/or human health. Zinc, copper and nickel may be toxic to plants when used at high application levels. Cadmium may be hazardous to the food chain if concentrations are high. Other trace elements, including chromium, mercury, lead, boron, molybdenum, cobalt, and selenium, are usually at low levels in sludge and do not affect plant growth or human health.

Assuming acceptable concentrations of trace elements and usage of sludge as a supplemental source of nutrients, an approximation of the benefits of sewage sludge is its value as a substitute for commercial fertilizer.

Table 7 provides estimates of the value of nutrients in sludge under six alternative assumptions for nutrient content and commercial fertilizer price. The nutrient content is based on data from the Ohio Guide for Land Application of Sewage Sludge.

Table 7. Value of One Ton of Dry Sewage Sludge Under Alternative Levels of Nutrient Content & Commercial Fertilizer Prices

	Value of Nutrients in Sludge	
	High	Low
Nutrient Content	N = \$.30/lb, P_2O_5 = \$.20/lb, K_2O = \$.11/lb	N = \$.20/lb, P_2O_5 = \$.15/lb, K_2O = \$.08/lb
High (N = 6.4%, P_2O_5 = 8.7% K_2O = .84%)[a]	\$49	\$36
Medium (N = 5%, P_2O_5 = 5.25% K_2O = .54%)	32	23
Low (N = 3.5%, P_2O_5 = 1.8%, K_2O = .24%)	15	10

[a]Approximately 30 percent of total N and 100 percent of P_2O_5 and K_2O would be available for crops.

The cost of sewage sludge disposal in the cities surveyed approximate the value of sludge as a substitute for commercial fertilizer. With current fertilizer prices, the right side of Table 6 would estimate sewage sludge values. Using the medium nutrient content for sludge, the benefits would be $23 per dry ton. For the average city surveyed it costs $31 per dry ton to spread sludge on the land with the benefits of the sludge being $10-$36 per dry ton.

The near equality of landspreading benefits and costs makes landspreading extremely attractive when compared with other methods of sludge disposal. Incineration, landfill, and landspreading are the primary disposal alternatives for the treatment plant operator. Incineration or landfill are practiced in many Ohio communities, but their costs are generally higher than landspreading.

Cost data from Ewing and Dick (1970) and Burd (1968) indicate that incineration costs are 2-3 times greater than the costs of landspreading of liquid sludge. Thus, we could expect to find incineration costs in the range of $50-$75 per dry ton. Generally, landfilling of sludge has higher costs than landspreading of liquid sludge. The costs of landfilling with dewatered sludge is approximately 67 percent higher than the disposal costs of landspreading of liquid sludge. Neither landfilling or incineration would offer any benefits to the municipality or landowner while landspreading would offer $10-$36 per dry ton if applied to crops as a partial substitute for commercial fertilizer.

Summary

Landspreading is receiving renewed interest as a method of sludge disposal due to a variety of price, institutional and attitudinal changes. Sewage sludge may be applied to land in an environmentally safe and economical manner; however, excessive application rates may prove injurious to the soil, plant growth, and water quality.

Results from a recently conducted survey point out the extent of current landspreading in Ohio and the current state of the arts in analysis, monitoring, application techniques and costs. About 50-60 cities currently are spreading sewage sludge on land. Forty-three of these cities were interviewed. These forty-three cities together spread about 100 dry tons of sludge per day. While the acreage covered by this quantity is a small percent of the total cropland, sludge application may affect large numbers of farmers, community officials and the community at large.

Survey results indicated that most Ohio municipalities which apply sludge to land had some notion of the quality of the sludge. Larger sewage treatment plants generally had better sludge testing programs. Several cities practiced only occasional sludge analysis, and approximately 20 percent did no sludge analysis.

Soil testing and soil monitoring programs were not being conducted by most municipalities. Water quality was being monitored by a high proportion of the surveyed cities.

Municipalities presently using land application ranked community reaction as being favorable to landspreading. Although a few officials have felt hostility from the local community, most have had no adverse community reaction. Several cities were using contracts between the municipality and private landowners in order to solidify the relationship within the community.

The economics of surveyed landspreading operations indicated that average sludge disposal costs declined as treatment plant size increases to 25 MGD. At this size level disposal costs averaged \$25 per dry ton. For the mean size of Ohio treatment plants, disposal costs averaged \$31 per dry ton. Benefits received from sludge range from \$10-\$36 per dry ton when used as a supplement for commercial fertilizer.

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